A teacher's (quick and dirty) guide to Carl Sagan's Cosmos

#MSUrbanSTEM

2016

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Carl Sagan's Cosmos: A personal voyage

The educator's perspective


Ch. 01
The known is finite,
the unknown infinite;
intellectually we stand on an islet
in the midst of an
illimitable ocean of inexplicability
Our business
in every generation
is to reclaim
a little more land
-T. H. Huxley, 1887

THE BIG IDEA(S)

- The Cosmos is expansive and Humans a natural curiosity, historically to explore the world around her/him.

WHAT THIS MEANS FOR STEM EDUCATORS

- We need to foster and support a mind set for discovery in our classrooms.
- Educators must think creatively to bring various elements such as technology, real world experiences and opportunities to explore to enhance learning.
- Educators must be willing to consider other's ideas of teaching and learning; and willing promote failing as a part of successful learning.
- Often times curiosity promotes enlightenment.
- It's ok not to know, it's not okay to be comfortable with not ever knowing.

CH. 1

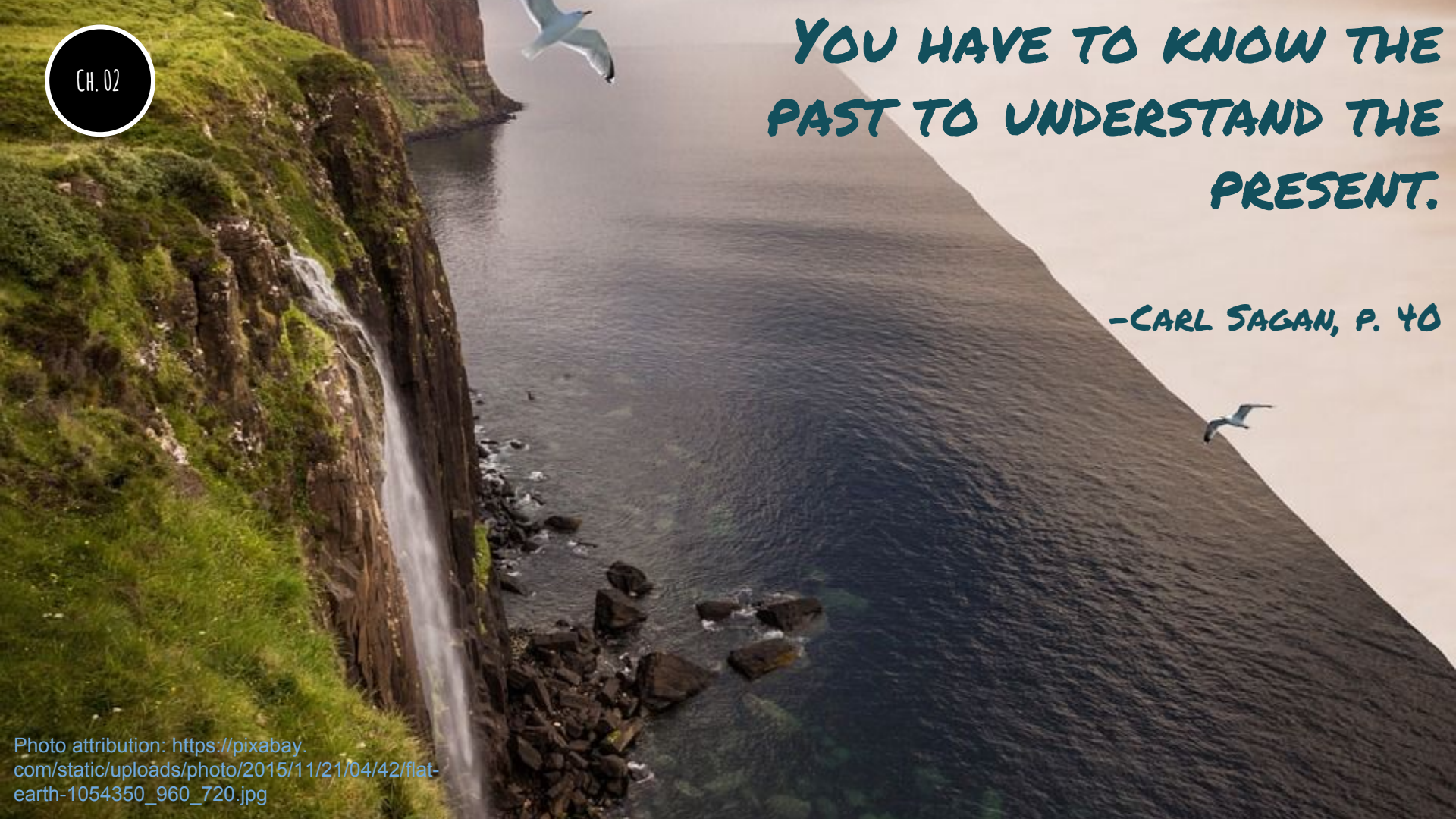
PERFORMANCES OF UNDERSTANDING

- Creating assessment/experiential learning that allow your students to show a deep conceptual understanding through application of knowledge.
- Each person constantly pushing his/her own understanding challenging previous notions and each generation extending man's (reclaiming) grasp of the universe (natural tendency to explore)
- Utilize activities like genius hour.

WHAT QUESTIONS DOES THIS RAISE?

- Will we be comfortable with our understanding of the universe? At what point will we stop wondering?
- Is curiosity dangerous?
- Are we okay with relearning concepts we thought we know and releasing control of learning to the students and understand the "WHY" we teach and "Why it's important?".

CH. 1



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THE BIG IDEA(S)

- Are we alone? To explore that, we must go beyond the study of just the Earth, though the Earth is a good place to start.
- "You have to know the past in order to understand the present"
- Evolution- "We humans look rather different from a tree...But down deep, at the molecular heart of life, the trees and we are essentially identical" (p. 35)

WHAT THIS MEANS FOR STEM EDUCATORS

- Teachers need to understand where their students' current knowledge lies so that we know where to start to dispel misconceptions
- Be aware of students' cultural worldviews, Example: getting students to think outside of a "Grand designer" for every individual species vs a common ancestor
- Activate students prior knowledge
- Depth instead of breadth
- "There is no predictive theory of biology, just as there is no predictive theory of history. The reasons are the same: both subjects are still too complicated for us" (p. 40)
  - We don't know it all!
  - We are still discovering so much about our own world and our universe
- Develop a curiosity for the world around us and question everything

CH. 2

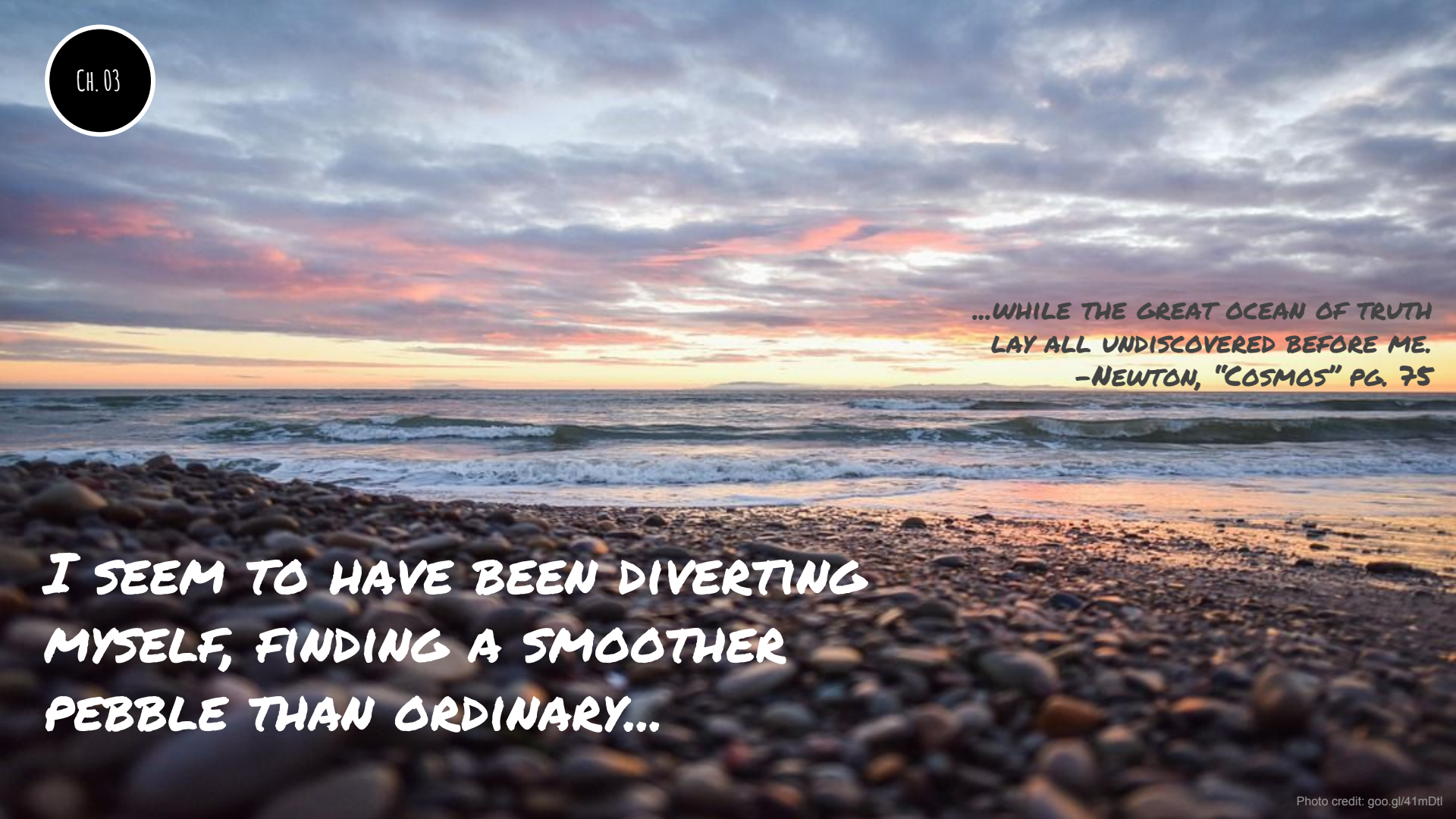
PERFORMANCES OF UNDERSTANDING

- Building molecular and polymer models
- Earlier grades, just investigating at the microscopic level plant and animal cells and showing relationships
- Comparative Anatomy investigation
- Create a timeline of Earth's evolution of life highlighting the Eras and Periods
- Create a skit to demonstrate major changes in Evolution from one period to another

WHAT QUESTIONS DOES THIS RAISE?

- When it is widely believed that over 99% of all species that ever existed are now extinct, and most life from the early times of the "Cambrian Explosion" did not leave fossil evidence, then how can we simulate this for students to understand?
- "There are tens of billions of known kinds of organic molecules, yet only about fifty of them are used for the essential activities of life"--how do we know for sure? In other words, will we discover new chemical compositions that support life elsewhere?

CH. 2


Ch. 03
...while the great ocean of truth lay all undiscovered before me.
-Newton, "Cosmos" pg. 75
I seem to have been diverting myself, finding a smoother pebble than ordinary...
Photo credit: goo.gl/41mDtl

THE BIG IDEA(S)

- "I do not know what I may appear to the world; but to myself I seem to have been only like a boy, playing on the seashore, and diverting myself, in now and then finding a smoother pebble or a prettier shell than ordinary, while the great ocean of truth lay all undiscovered before me." – Newton, pg. 75
- Studying the world around you can improve your life.
- Don't be afraid to look around and explore.

WHAT THIS MEANS FOR STEM EDUCATORS

- Important to show the beauty of the world.
- There's more unknown than known.
- Research should be supported with evidences.
- Mistakes are important. We can learn from those mistakes and advance our knowledge.
- Clinging to incorrect assumptions in the face of opposing evidence holds us back.
- Taking academic risks requires bravery.

CH. 3

PERFORMANCES OF UNDERSTANDING

- Develop a timeline of scientific discovery
- Laboratory discussions of results -> dig out mistakes and how to learn from them
- Create a world of wonder
- Debate between two different viewpoints
- Inquiry based activities

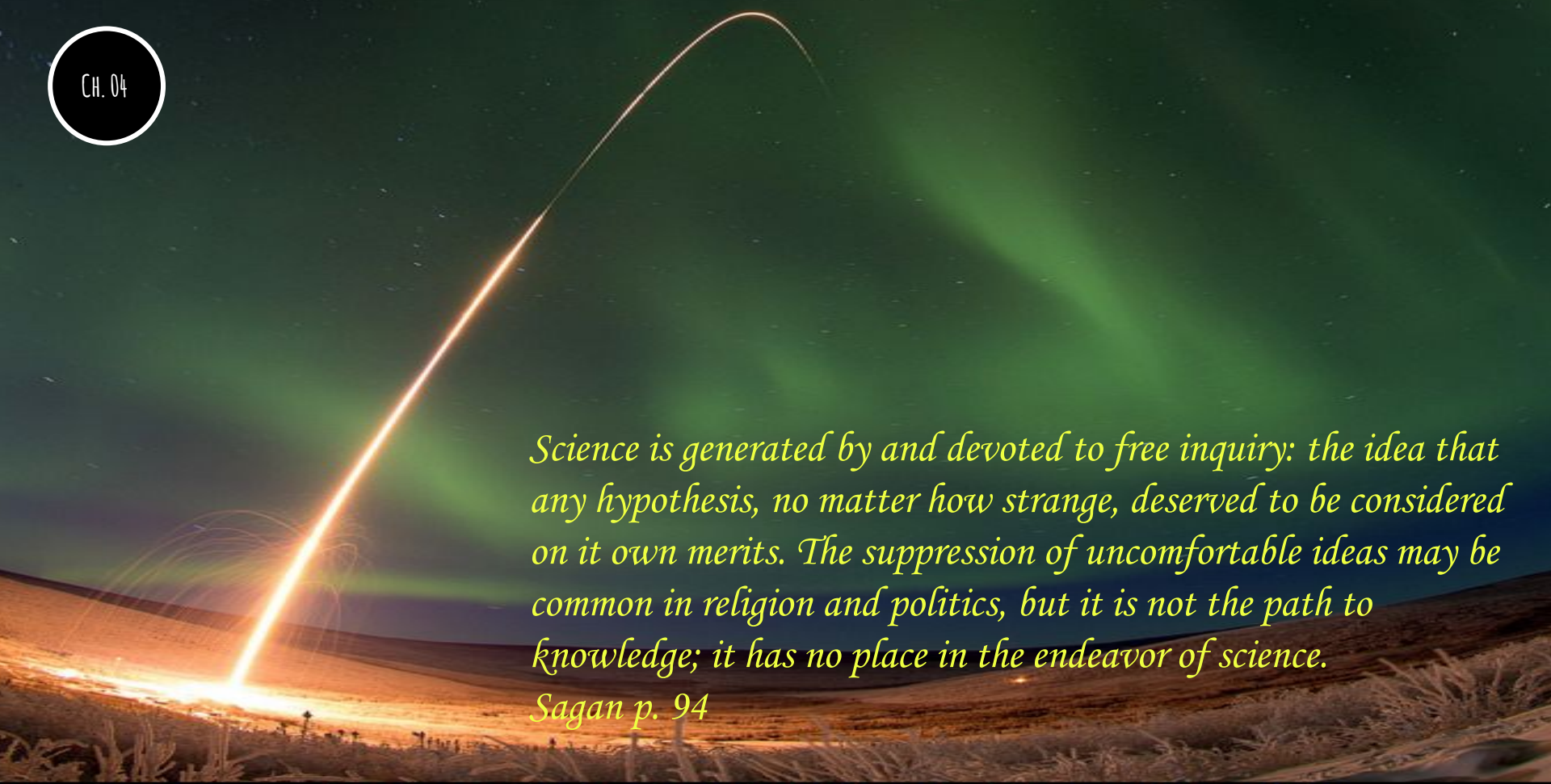
WHAT QUESTIONS DOES THIS RAISE?

- How do we help students see beauty in everyday objects?
- How do I know I'm part of the problem instead of the solution?
- How do I encourage students to take academic risk?
- How do I help students understand that mistakes are useful?

CH. 3

Ch. 04

Science is generated by and devoted to free inquiry: the idea that any hypothesis, no matter how strange, deserved to be considered on it own merits. The suppression of uncomfortable ideas may be common in religion and politics, but it is not the path to knowledge; it has no place in the endeavor of science.
Sagan p. 94



THE BIG IDEA(S)

WHAT THIS MEANS FOR STEM EDUCATORS

- "Science is generated by and devoted to free inquiry; the idea that any hypothesis, no matter how strange, deserves to be considered on its merits. The suppression of uncomfortable ideas may be common in religion and politics, but that is not the path to knowledge; it has no place in the endeavor of science."
  – Sagan, page 94
- Ideas need to be supported by evidence, the Earth is fragile for exterior and man made reasons

Teachers should:

- Nurture the whole student
- Emphasize that it is ok to be wrong
- Encourage risk taking
- Expect students to support their opinions with evidence

We need to help students:

- Formulate a hypothesis
- Evaluate evidence and be aware that "science" can be used to advance a point of view
- Accept that ideas once held dear can turn out to be wrong
- Demonstrate perseverance during the inquiry process
- Understand that our planet is tiny compared to the rest of the universe and also that humanity is a short lived newcomer in that universe
- Understand that the planned and unplanned effects of our technology can be ambiguous

CH. 4

PERFORMANCES OF UNDERSTANDING

- ☐ Host class debate of controversial science theory or topic and document on social media
- ☐ Research an unexplained event and all of the possible explanations
- ☐ Critically analyze popular science articles in formal writing. This could include misconceptions, political points of view, economic motivations
- ☐ Research a non profit and one of the causes they support and conduct a service learning project around that cause
- ☐ Comparative analysis of Venus and Earth (Heaven and Hell) using some form of the arts

WHAT QUESTIONS DOES THIS RAISE?

- ☐ How many people on this planet earn their living by protecting us from incoming meteors?
- ☐ How do we get students invested in creating solutions for today's global problems?
- ☐ How can we help our students become freethinkers who are comfortable saying "I don't know"?
- ☐ How do we change incorrect, preconceived ideas?
- ☐ How do we balance between creative thinking and factual evidence?
- ☐ How do we promote that inquiry, skepticism and appreciation of evidence are lifelong habits?

CH. 4

Ch. 05;
PAGE 141

THE BIG IDEA(S)

- If the planet ever is terraformed, it will be done by human beings whose permanent residence and planetary affiliation is Mars. The Martians will be us. Sagen p.141

WHAT THIS MEANS FOR STEM EDUCATORS

- Science is tentative and with new information and technology ideas can change.
- Science relies on data.
- Rely on current data to inform your practice
- We have to initiate any changes to our practice
- We should be willing to try new things without predicting the outcome.

CH. 5

PERFORMANCES OF UNDERSTANDING

Inquiry based hands-on exploration
Student led discussions and questioning
Student generated procedures on experiments (Supporting Claims with Evidence)
Student led self-assessment

WHAT QUESTIONS DOES THIS RAISE?

- Will Lowell's premonition come true one day?
- When will we get there?
- Will the world ever be able to cooperate and coexist as a united planet?

CH. 5

CH. 06

Chapter 6: Travelers' Tales

This is the time when humans have begun to sail the sea of space. P. 142

THE BIG IDEA(S)

- Epic voyages of discovery- the opening and broadening of views of freedom, science, art, technology, and opinions and thought.

WHAT THIS MEANS FOR STEM EDUCATORS

- Consequences of close-mindedness
- Importance of freedom of thought
- Scientific breakthroughs can be the result of tinkering and exploring with no specific goal
- Teaching students to explore, question, take risks
- Designing given constraints
- What possibilities exist for future exploration?
- How to create solutions for unknown constraints in exploring.

CH. 6

PERFORMANCES OF UNDERSTANDING

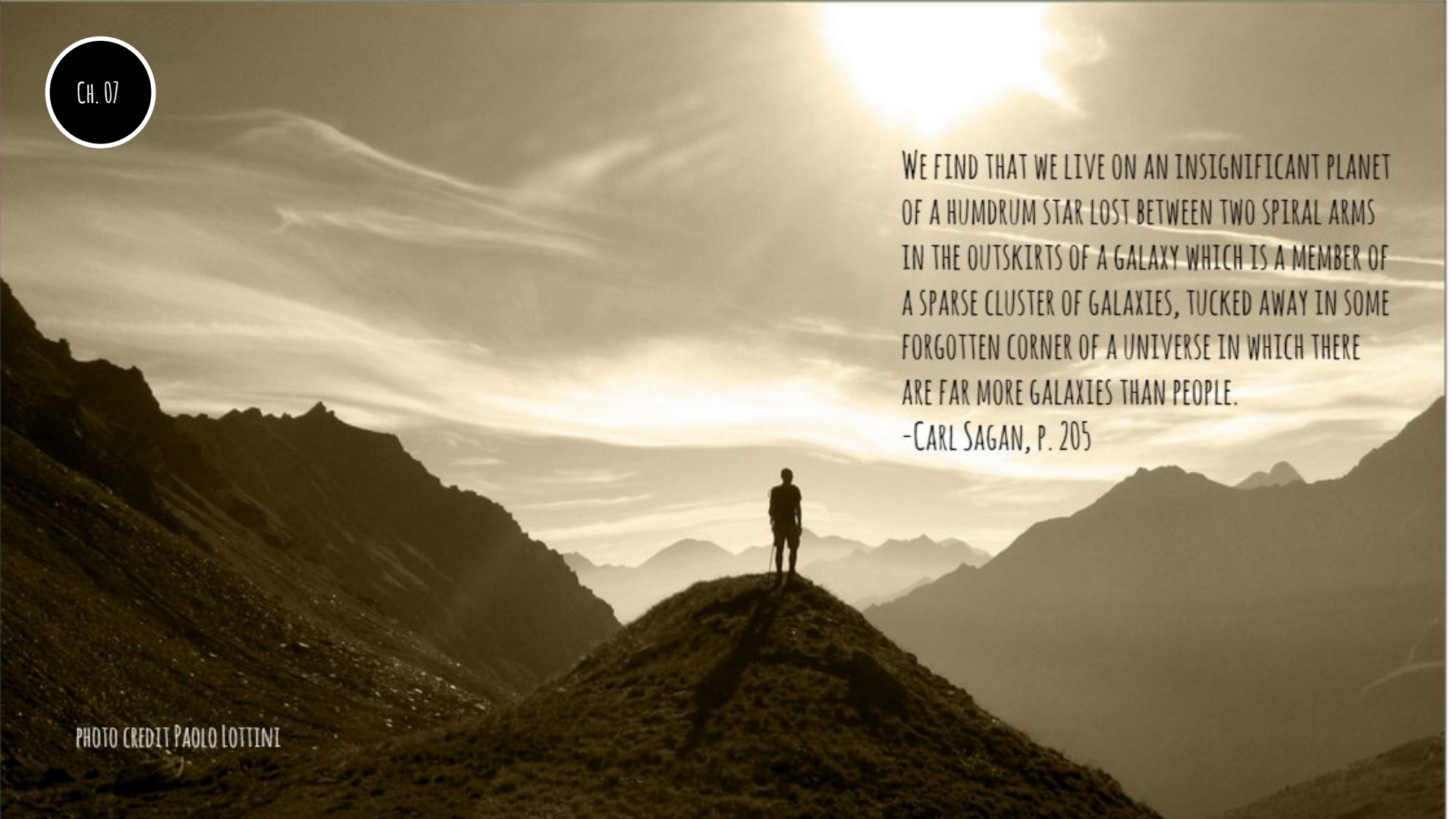
- Design a solution to a problem given constraints, reflecting on the process and results.
- Create a product that demonstrates analogous rates of the ships' journeys (historical and present time) and each student's personal experiences.
- Determine the rates of exploration historically and in present time and use the pattern to determine how far humans will be able to explore in 100 years. Use this information to research a potential a destination and create a flight plan.
- Role-play potential historical interactions of intellectuals in the context of societies being open- or close- minded to exploration.

WHAT QUESTIONS DOES THIS RAISE?

- How do we help students become open-minded?
- How do we help students become risk-takers?
- How do we teach students to analyze others' ideas- recognizing productive and unproductive aspects of their peers' arguments?
- How do we as teachers incorporate conceptual, interdisciplinary learning opportunities within the constraints of our content areas?

CH. 6

Ch. 07



We find that we live on an insignificant planet of a humdrum star lost between two spiral arms in the outskirts of a galaxy which is a member of a sparse cluster of galaxies, tucked away in some forgotten corner of a universe in which there are far more galaxies than people.
-Carl Sagan, p. 205

photo credit Paolo Lottini

THE BIG IDEA(S)

- The universe is so massive and as humans we are a small part of this universe.
- We think the world revolves around us but in reality we only have a tiny understanding of the universe around us.
- Humans have always tried to make sense of the natural world – first with stories and later with science.

WHAT THIS MEANS FOR STEM EDUCATORS

- Our knowledge of the cosmos/universe is limited. There is much to be learned.
- Learning takes place through trial and error.
- Ideas that may lead to amazing discoveries may seem bizarre at first; do not stifle creativity.
- Embark on a voyage based on a question first.
- Just because someone has a valid idea, that does not mean that all their ideas our valid. It is important to evaluate each theory and idea independently.
- Theories and ideas have evolved over the centuries.
- Culture and beliefs have and continue to play a big part in scientific discoveries.

CH. 7

PERFORMANCES OF UNDERSTANDING

- Students pose their own questions. W.O.W. moments that lead to independent learning.
- Question, research, debate, justify, revise, generalize
- Create a timeline of the universe or planet Earth and mark important events.
- Create a scale model of the solar system, or the galaxy, or the universe.
- Research important scientists and their discoveries and create Memes based on research.

WHAT QUESTIONS DOES THIS RAISE?

- How does the scale of the universe impact our understanding of our place in the universe?
- What else is out there in the universe? Are we alone?
- What knowledge has been lost over the decades? Centuries? Millenia?
- Can we teach for conceptual understanding without full knowledge of the subject?

CH. 7


Ch. 08
Space and time are interwoven.
We cannot look out into space
without looking back into time.
-Carl Sagan Cosmos Pg. 212
http://genius.com/2112948

THE BIG IDEA(S)

"Space and time are interwoven. We cannot look out into space without looking back into time."

Thought experiments are confirmed through technology, yet technology generates new thought experiments that could replace the old.

WHAT THIS MEANS FOR STEM EDUCATORS

Educators need to

- ☐ Understand how technology improves and enhances ideas
- ☐ Understand that students ideas shouldn't be rejected and time should be given for discovery
- ☐ Use various questioning techniques that develop students critical thinking skills
- ☐ Provide opportunities for reflections
- ☐ Nurture students insights
- ☐ Create knowledgeable backgrounds about astronomy

CH. 8

PERFORMANCES OF UNDERSTANDING

- Students should complete activities that utilize the Engineering design process that focuses on the process and not the solution
- Students should complete activities that forces collaborations and communication
- Students should be involved in activities that involve deep discussions and debate
- Problem based learning activities that allows students to explore real-world problems and challenges and acquire a deeper knowledge
- Students should create videos that defends/supports their position
- Students use social media as a sounding board that supports/defends their ideas

WHAT QUESTIONS DOES THIS RAISE?

- If Atoms from stars created us, when we look at the stars, are we looking at ourselves?
- If no one appreciates the magnitude of the Cosmos, is it still magnificent?
- How do we invoke conceptual change around space and time?
- If you run out of time, do you run out of space?
-

CH. 8

Ch. 09

https://www.flickr.com/photos/jdhancock/3658631267

"When consider cutting an apple pie, continuing down beyond a single atom, we confront an infinity of the very small. And when we look up at the night sky, we confront an infinity of the very large."

THE BIG IDEA(S)

- Everything in the known Universe is related through common components of matter that are continuously recycled
- We are all made of "star stuff"

WHAT THIS MEANS FOR STEM EDUCATORS

We need to help students...

- Understand that life and the universe is always evolving
- Understand the relationship between themselves and other things
- To question and investigate relationships and interconnectedness of everything
- Their scientific understanding can be applied in many disciplines.
- To use scale to show examples of relationships
- They are part of something bigger than what is known in "their universe"
- Things that you may think are not related, have many things in common if looked at in greater depth

CH. 9

PERFORMANCES OF UNDERSTANDING

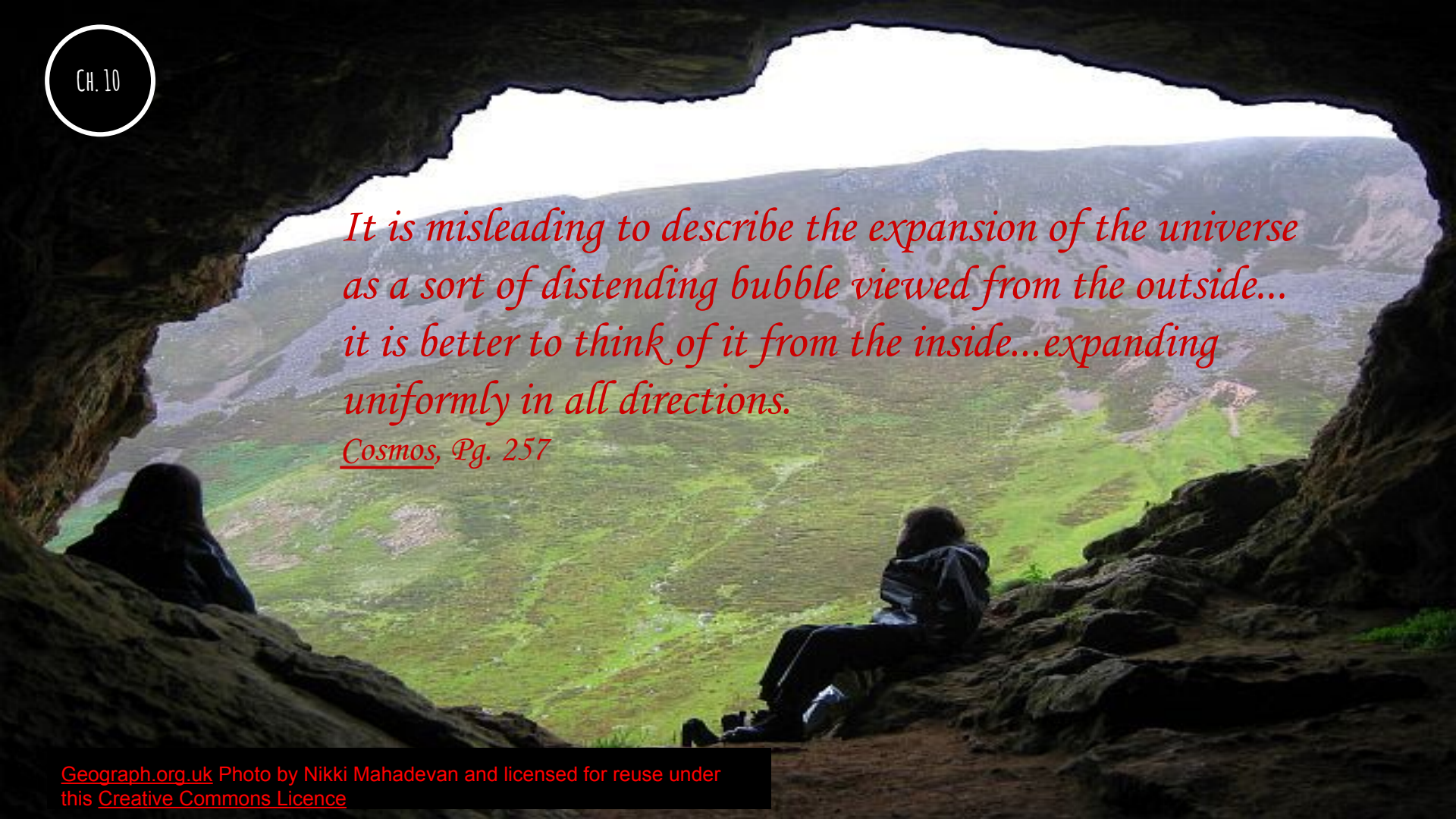
- How are things similar/different?
- Using scale to find commonality, compare and contrast
- Finding mathematical relationships of yourself to desk, school building, Willis Tower, distance to sun
- Connecting the large processes that are also happening at a smaller scale
- Providing examples of reactions and processes that are happening on Earth and in the greater universe
- Comparing and contrasting the composition of the earth to other planets

WHAT QUESTIONS DOES THIS RAISE?

- Why are there basic building blocks?
- How does conscious life arise from matter?
- What is the difference between living and nonliving matter?
- How do we help them see that they are part of something greater?
- How do we help students understand that things that look different on the outside are similar when we look inside? How do we help students understand perspective?

CH. 9

Ch. 10



It is misleading to describe the expansion of the universe as a sort of distending bubble viewed from the outside... it is better to think of it from the inside...expanding uniformly in all directions.

Cosmos, Pg. 257

THE BIG IDEA(S)

- **It is misleading to describe the expansion of the universe as a sort of distending bubble viewed from the outside… it is better to think of it from the inside…expanding uniformly in all directions.** Pg 257
- We can make an analogy with the growth of the universe and our students education. Expansion comes from inside-out growth.
- How do we encourage our students to expand their minds, perhaps without imposing an external mandate?
- How can facilitate students' understanding of space inflation theory vs big bang theory

WHAT THIS MEANS FOR STEM EDUCATORS

- The expansion of STEM education comes from the paradigm shift that must first take place within educators.
- STEM education growth will be directly affected by teacher pre-service training and how curriculum designers understand what and how children learn.
- Teachers need to access the technological level of their students

We need to help students…

- Self-assess and value the internal changes in their thinking rather than solely measuring their growth on external measurements such as grades and test scores.
  - Identify "soft skills" we can measure (collaboration, GRIT,)
  - Create SMART goals for themselves
  - Use a tracker for Standards-based grading
- Understand the limits of the models we use to understand the universe (we cannot visualize an expanding bubble with no "outside")

CH. 10

PERFORMANCES OF UNDERSTANDING

- Students create a timeline for the growth of the universe, extrapolate to what could happen in the future. Then, students compare that with the growth of their understanding of a certain topic
- The start of the universe is no longer thought of as a Bing Bang at one point, but rather as an expansion of space (or lack thereof) in many places at once.
- Students can think of examples where their understanding came not from one big explosion (eureka) but after a prolonged conceptual change.

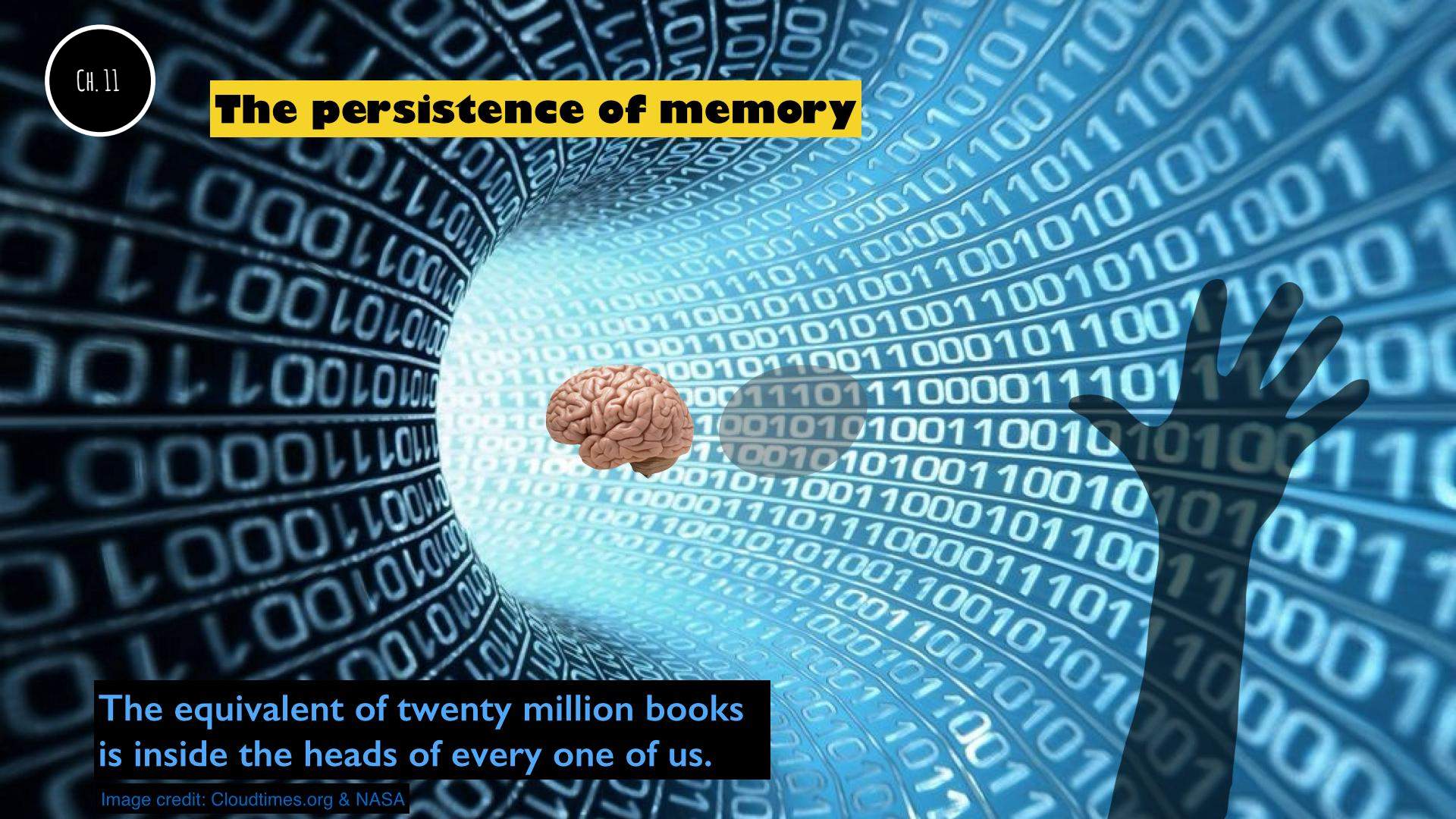
WHAT QUESTIONS DOES THIS RAISE?

- With gravitational waves, we finally have a "smoking gun" for space inflation (and the lack thereof for our universe). It goes against the idea of a single point Big Bang. Why was the Big Bang theory so prevalent? What assumptions were made for this theory? How long will folks hold on to the Big Bang theory?
- Will the Universe keep expanding? Is it possible that we can keep expanding human understanding? That intuitive sense of whatever expands must eventually contract??
- What does it look like if you have a large collection of people focused on expanding their mind and understanding from within? How would they interact together?

CH. 10

CH. 11

The persistence of memory



The equivalent of twenty million books is inside the heads of every one of us.

Image credit: Cloudtimes.org & NASA

THE BIG IDEA(S)

- Intelligence can be seen in computers, whales, DNA, human brains, and man-made structures such as cities, libraries, books and satellites). Can it exist in other worlds?

WHAT THIS MEANS FOR STEM EDUCATORS

- Allows us to to see intelligence as being contained in broader contexts than merely the brain.
  - Computers and intelligence – bits and bytes as basic units of information
  - Consider animal intelligence (as exhibited by whales and their unique mode of communication)
  - The role of DNA and other genetic forms of intelligence
- Intelligence lies in the brain
  - The evolutionary aspects of developing human intelligence
- Intelligence lies in structures made by humans
  - Cities, libraries, books, computers, satellites as all being forms of inhabiting collective intelligence.
- The distinct possibility of alien intelligence
  - The odds for and against
  - Communicating with alien intelligences (how can it be done)

CH. 11

PERFORMANCES OF UNDERSTANDING

- Define intelligence
  - And its many manifestations on this planet
  - Recognizing intelligent behavior
- Provide examples of intelligence in humans, animals, cities and computers
  - Discuss how this has implications for the development of alien intelligence
- Life on other worlds
  - Challenges to the origin of life on other worlds
  - The probability of life on other worlds
- Communicating with alien intelligences
  - Mathematics v.s. Music

WHAT QUESTIONS DOES THIS RAISE?

-

CH. 11

Ch. 12

Encyclopedia Galactica

Is there anyone
out there to talk to?

Image credit: NASA

THE BIG IDEA(S)

- Can there be intelligent life elsewhere in the universe
  - How can we find out
- Learning to distinguish between fact and fiction with respect of alien civilizations

WHAT THIS MEANS FOR STEM EDUCATORS

- Students research the internet and debate the definition of life?
  - How can be recognize life or intelligent life in other parts of the universe
  - Truth and fraud in the search for intelligent life
  - The nature of science and the distinguishing non-science from science
  - Find examples in the news of non-science and science
- Students study the electromagnetic spectrum and the importance of of radio waves for the search for intelligent life
- Students seek to identify the variables that can help predict the evolution of life
  - Can one compute the probability of intelligent, technologically sophisticated civilizations in the universe (Drake equation)
  - Students study the discovery of planets across neighboring stars and the presence of planets in the "Goldilocks" zone
- Students develop their own "messages" to send to aliens.

CH. 12

PERFORMANCES OF UNDERSTANDING

- Students debate and attempt define life. How can we distinguish life from non-life?
- Students debate and attempt to define intelligence?
- Students explore the idea that computers can be intelligent?
  - Students play the Turing Test against "bots" on the Internet?
  - Watch the moving "The imitation game" and debate the value of the Turing test
- Students explore on the internet and find examples of animal intelligence.
  - Students attempt to define what makes it different from human intelligence?
- Debate questions: Is intelligence an inevitable consequence of evolution?
  - Does intelligence necessarily mean technological proficiency?
  - How can one communicate with intelligent beings? Animals? Aliens?

WHAT QUESTIONS DOES THIS RAISE?

Ch. 13

Who Speaks for Earth?

"*We* speak for Earth. Our obligation to survive is owed not just to ourselves but also to that *Cosmos*, ancient and vast, from which we spring."

– Carl Sagan, pg. 365

THE BIG IDEA(S)

"There is no other species that does science…it's **not perfect**, it can be misused, it is **only a tool**, but is by far the **best tool** that we have. It is **self-correcting, on-going, applicable to everything.**" pg. 352

Value knowledge and act wisely to pass this knowledge on. **Apply** your understanding and **share** your passion with others to **create** enthusiasm. **We cannot stand alone.**

WHAT THIS MEANS FOR STEM EDUCATORS

We need to help students…

- Understand that science is always evolving.
- Critically examine what is known as truth.
- Question authority, ask why, explore how.
- Develop a passion for the discipline and share it with others.
- Apply their understanding, as they are aware that they are a part of a bigger system.
- Understand that science is a powerful tool that needs to be wielded responsibly.
- See the evolution of technology and its significance in science.
- Consider how they impact the system and respond appropriately.

CH. 13

PERFORMANCES OF UNDERSTANDING

- Research and present theories that have been disproved.
- Working in pairs, students are provided a fact. One student provides evidence and proof that the fact is true. The other student contradicts the evidence to weaken the validity of the claim.
- Students share their curiosities on a "Wonder Wall" in the classroom.
- Students tweet or connect with a field expert around a STEM topic of interest. Through their discussion with the expert, students are able to explore new levels of understanding by utilizing probing questions.
- Students create independent passion projects (20% time, Genius Hour, etc.). They then share their inquiry with other students through presentation as well as with family and community members.
- Class participates in a science social activist campaign and educates the community on environmental issues that challenge them. Students provide potential solutions to better educate community members.
- Students create a social media campaign (YouTube Channel, Instagram hashtag) to document and share their scientific understanding in an accessible way.

WHAT QUESTIONS DOES THIS RAISE?

- How do we help students to ask more beautiful questions about our world?
- How do we help our students become more critical of the truth, especially in the age of the Internet?
- With the ability to disprove, how can we ever be fully sure that facts are facts?
- How do we help our students see that science is not a solo discipline, but collaborative when there are so many contradictory examples in the field?

CH. 13

The End